Air Force Civil Engineer Center

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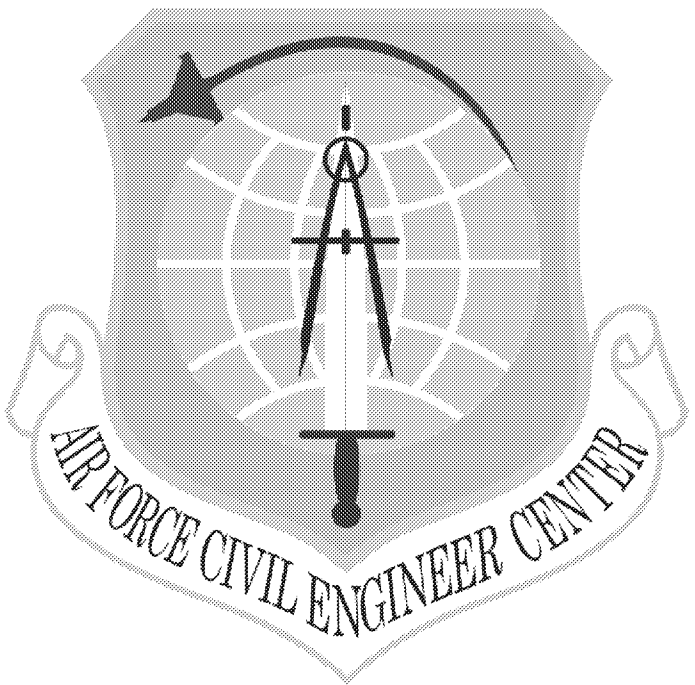


FORMER
WILLIAMS AIR FORCE BASE

Site ST012
Former Liquid Fuels Storage Area
Remedial Action

BRAC Cleanup Team Call
21 January 2016

Site ST012 Update

- Steam Enhanced Extraction (SEE) Operations Progress
- Near-term SEE Operational Plan
- Review of Transition Criteria

SEE System Operational Status Overview

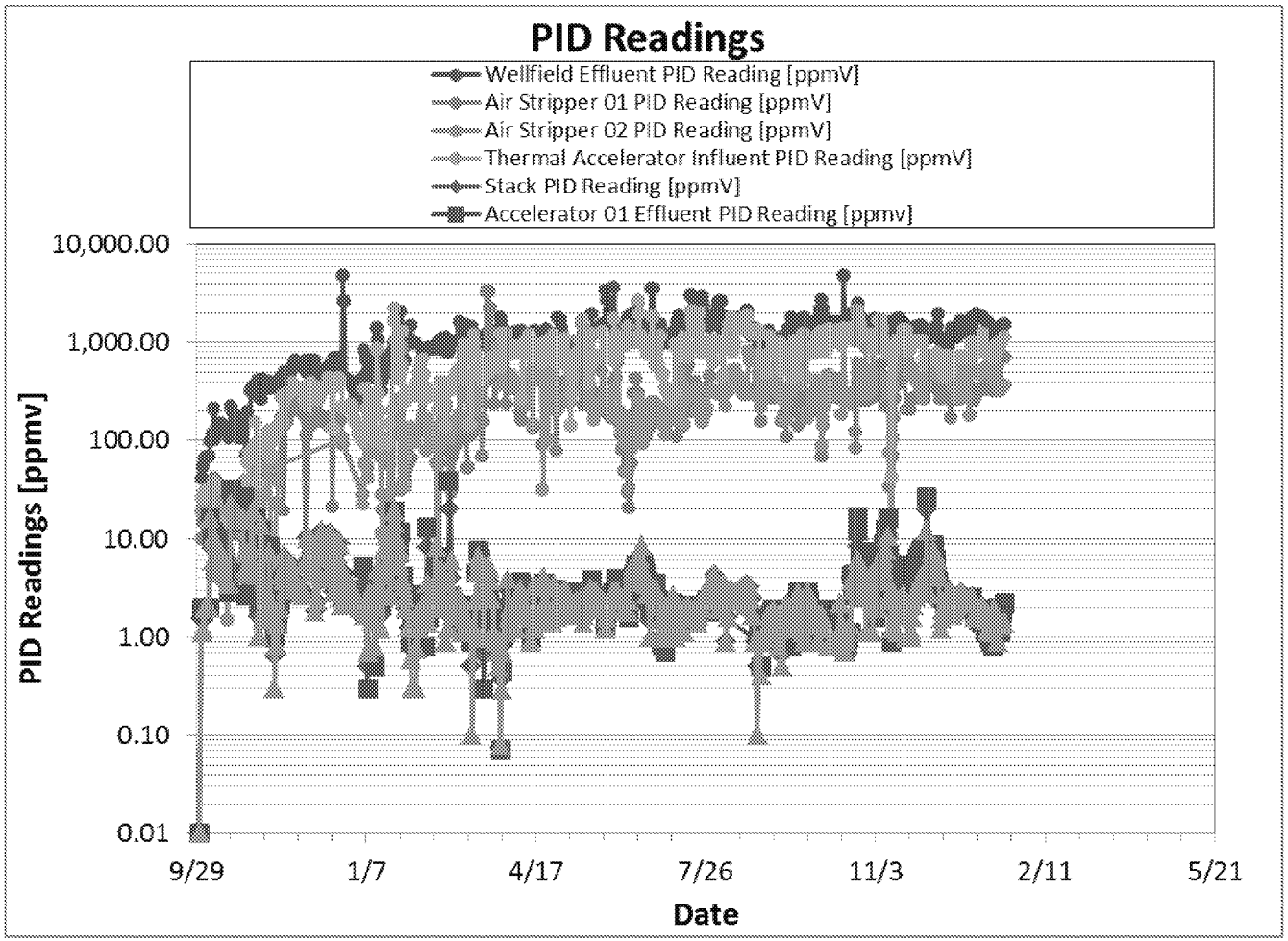
Site ST012 SEE System Status Summary (through 18 January)

	Value	Unit
Target Treatment Zone (TTZ) Soil Volume	410,000	cubic yards (cy)
Area	199,000	square feet (ft^2)
Upper Depth of Treatment	145	feet (ft) below ground surface (bgs)
Lower Depth of Treatment	245	ft bgs
Vapor Liquid Treatment Started	09/29/14	
Thermal Operations Started	09/29/14	
Last Process Data Update	01/18/16	
Last Temperature Data Update	01/18/16	
Estimated Total Days of Operation	422	days
Days of Operation	476	days
Days of Operation vs. Estimate	113	percent (%)
Estimated Total Energy Usage	11,343,000	kilowatt hours (kWh)
Total Energy Used	4,850,503	kWh
Used Electrical Energy vs. Estimate	43	%
Total Steam Injected	285.4	million pounds (lbs)
Projected Total Steam Injection	320	million lbs
Steam Injected Vs Projected	89	%
Total Mass Removed in Vapor Based on Photoionization Detector (PID) Readings	1,016,158	lbs
Total Mass Removed as NAPL	1,286,793	lbs
Average Daily NAPL Mass Removal Last Week	2,264	lbs/day
Total Vapor and Liquid Mass Removal (based on PID readings)	2,302,951	lbs
Average Power Usage Rate Last Week	457	kilowatts (kW)
Average Wellfield Vapor Extraction Rate Last Week	357	standard cubic feet per minute (scfm)
Average Condensate Production Rate Last Week	0.2	gallons per minute (gpm)
Average Water Extraction Rate Last Week	122	gpm
Total Water Extracted	74,755,776	gallons
Total Recovered Light Non-Aqueous Phase Liquid	195,859	gallons
Average Water Discharge Rate Last Week	175	gpm
Total Treated Water Discharge	100,081,000	gallons

ST012 SEE Operational Progress

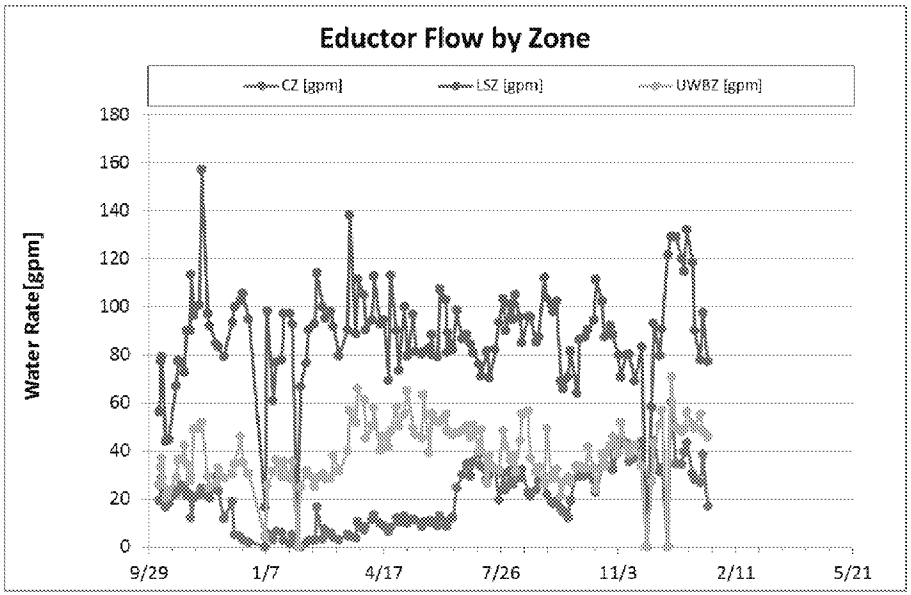
- **SEE System Operations** **8 December – 18 January**
  - A complete depressurization of all three zones in the wellfield was initiated on 28 December 2015
  - Average liquid extraction rate of 129 gpm
  - Typically five to six eductor skids were online at a time
  - Average steam injection rates prior to depressurization were 8,200 lbs per hour in the LSZ, 4,650 lbs per hour in the UWBZ, and 4,050 lbs per hour in the CZ
  - Thirty-two steam wells online – injection rates at wells have varied due to pressure cycling conducted in the CZ, LSZ and UWBZ
  - SEE discharge continues to meet compliance standards

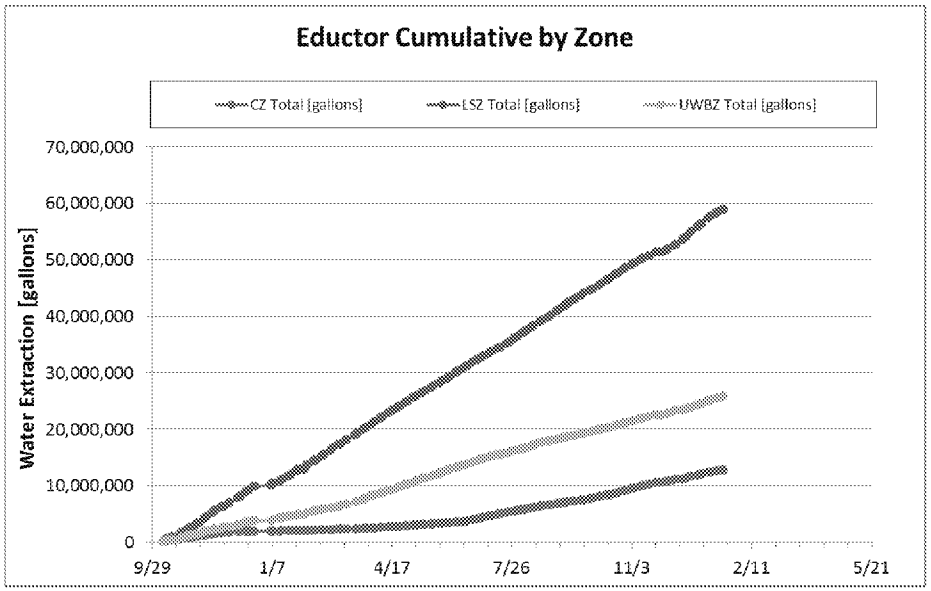
Site ST012 SEE System Photoionization Detector (PID) Readings



Vapors continue to be rich in organics

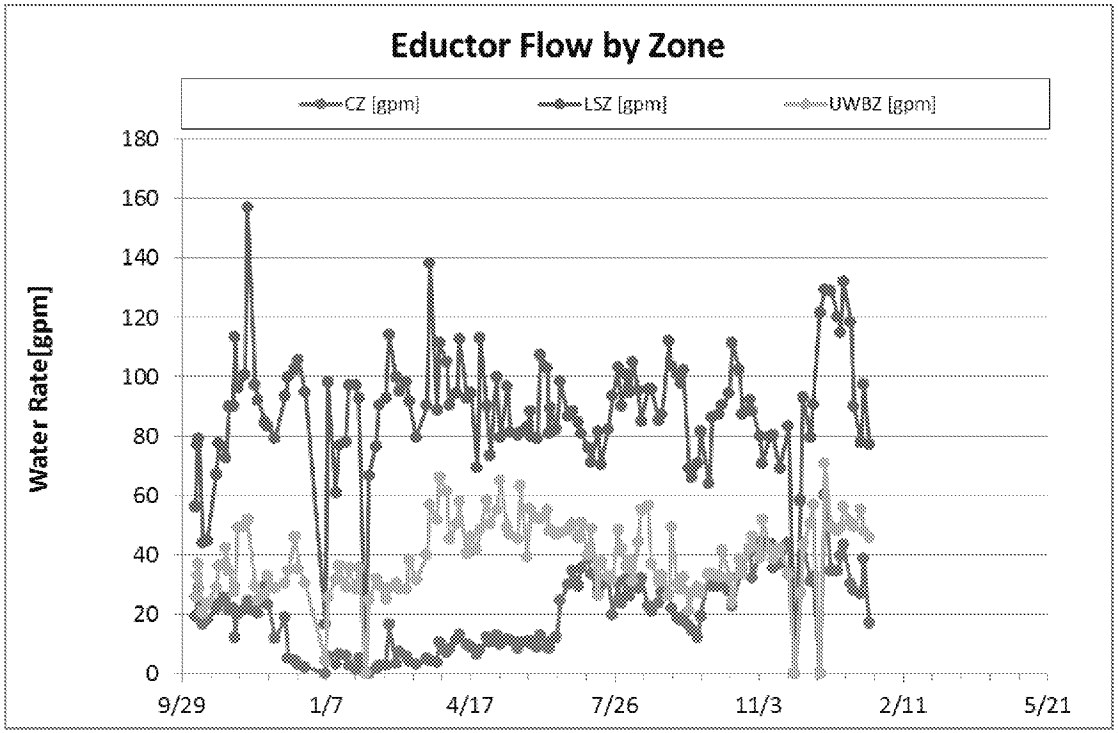
Site ST012 SEE System Water Extraction by Zone





- **Eductor extraction rates per zone are based on individual eductor feed and return meters**
- **Extraction: injection ratio for the period 8 December to 18 January based on average flows**
  - **CZ: 8 December 2015 – 18 January 2016 period: 3.3:1**
  - **UWBZ: 8 December 2015 – 18 January 2016 period: 4.4:1**
  - **LSZ: 8 December 2015 – 18 January 2016 period: 5.5:1**

Site ST012 SEE System Injection/Extraction Balance

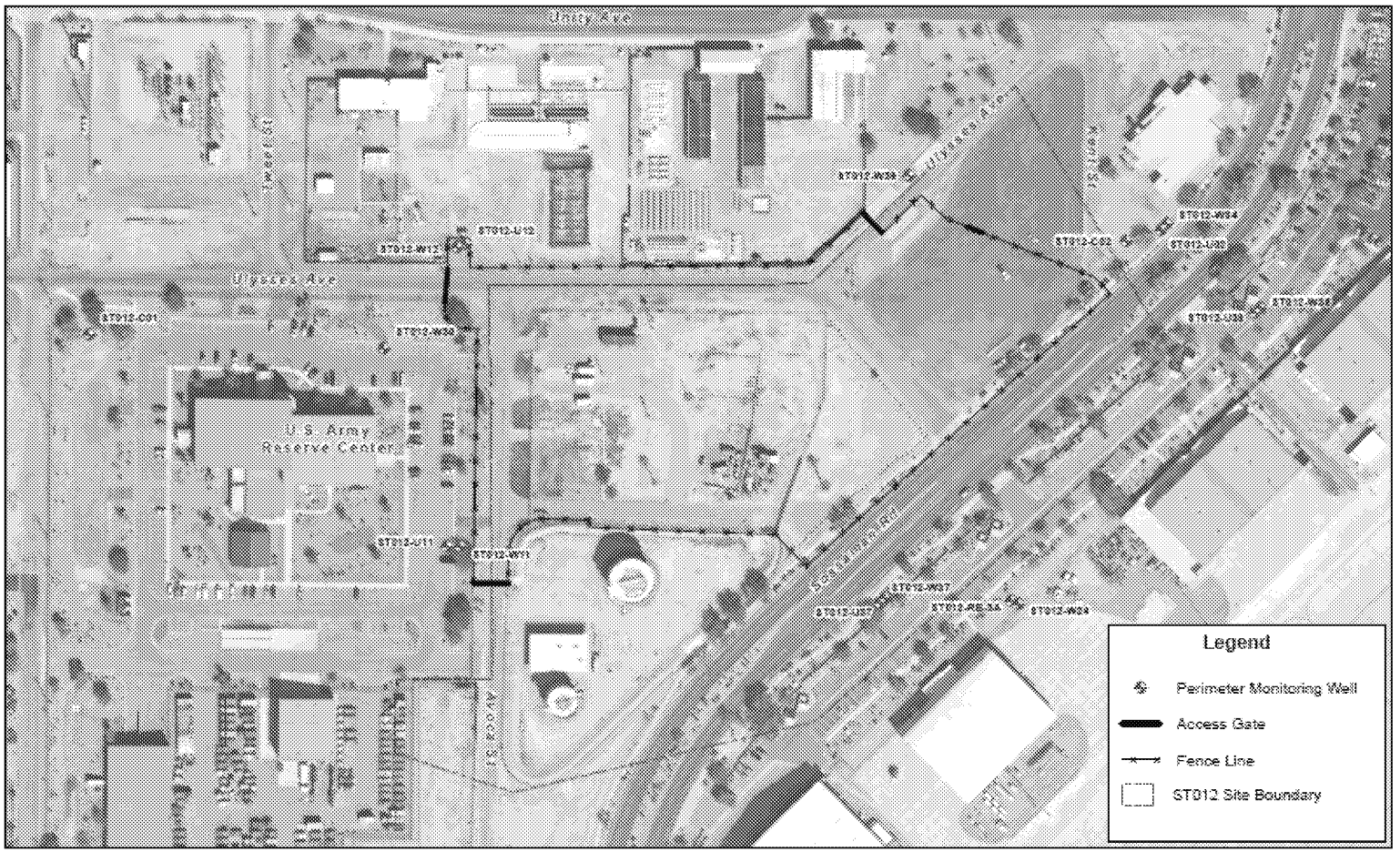


	CZ	UWBZ	LSZ
	[gallons]	[gallons]	[gallons]
Water extracted	12,760,000	25,840,000	58,896,000
Water injected (as steam)	3,087,000	8,448,000	22,744,000
Net extraction	9,673,000	17,392,000	36,152,000

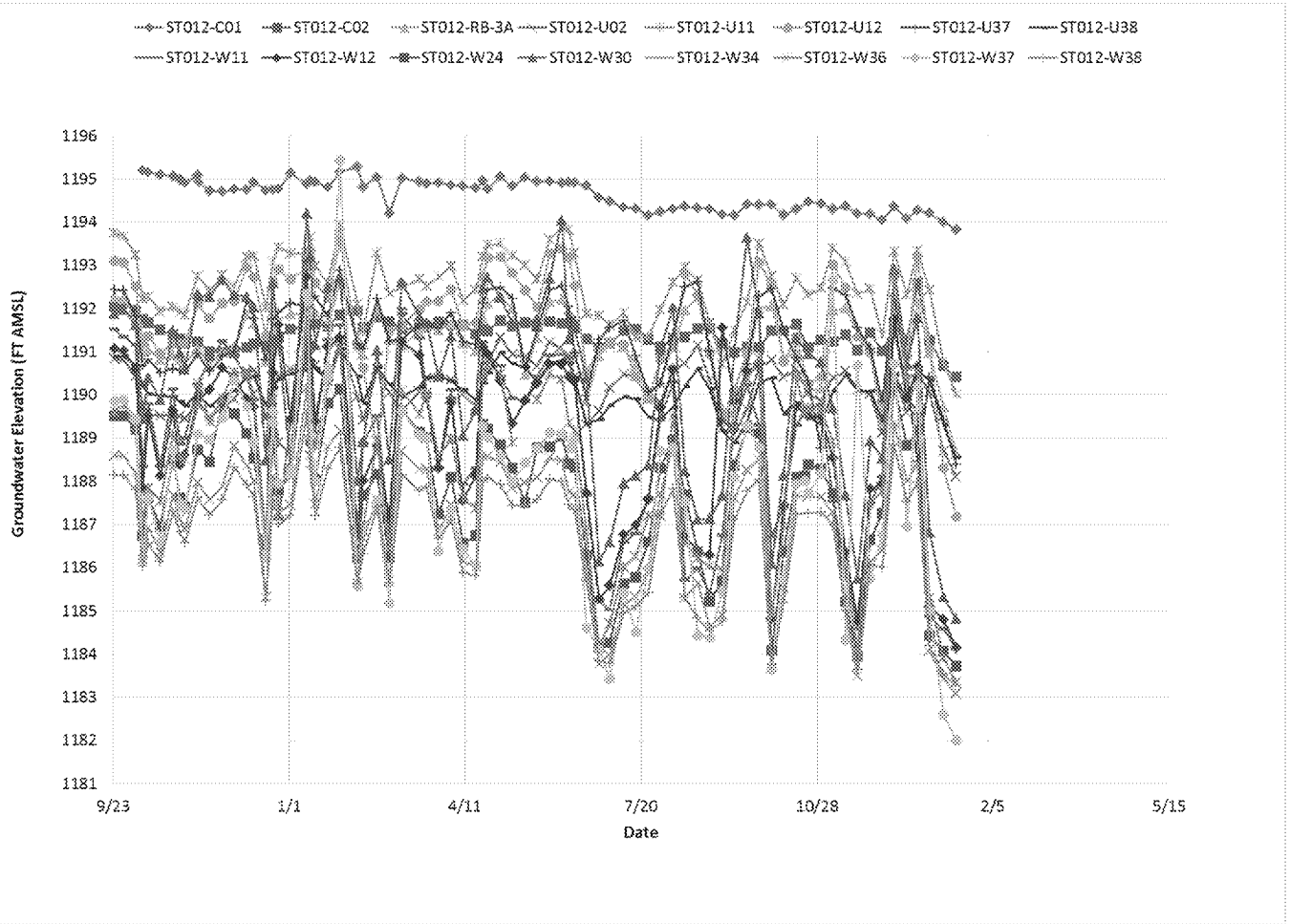
Note: water extracted to date per zone is based on individual eductor meters

ST012 Perimeter Groundwater Monitoring

Site ST012 SEE Perimeter Groundwater Monitoring Wells



Site ST012 SEE Perimeter Groundwater Elevations



Water level increases are temporary

Site ST012 SEE Perimeter LNAPL Thicknesses (ft)

Monitoring Well	12/24/2015		12/31/2015		1/8/2016		1/15/2016	
CZ/UWBZ Wells	Before bailing	After Bailing	Before bailing	After Bailing	Before bailing	After Bailing	Before bailing	After Bailing
ST012-C01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-C02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UWBZ Wells								
ST012-U02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-U11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-U12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-U37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-U38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-RB-3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSZ Wells								
ST012-W11	6.97	0.17	3.29	3.29	4.72	4.72	5.01	5.01
ST012-W12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-W24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-W30	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
ST012-W34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-W36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ST012-W37	93.41	41.26	81.26	44.98	75.20	25.00	72.21	27.13
ST012-W38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

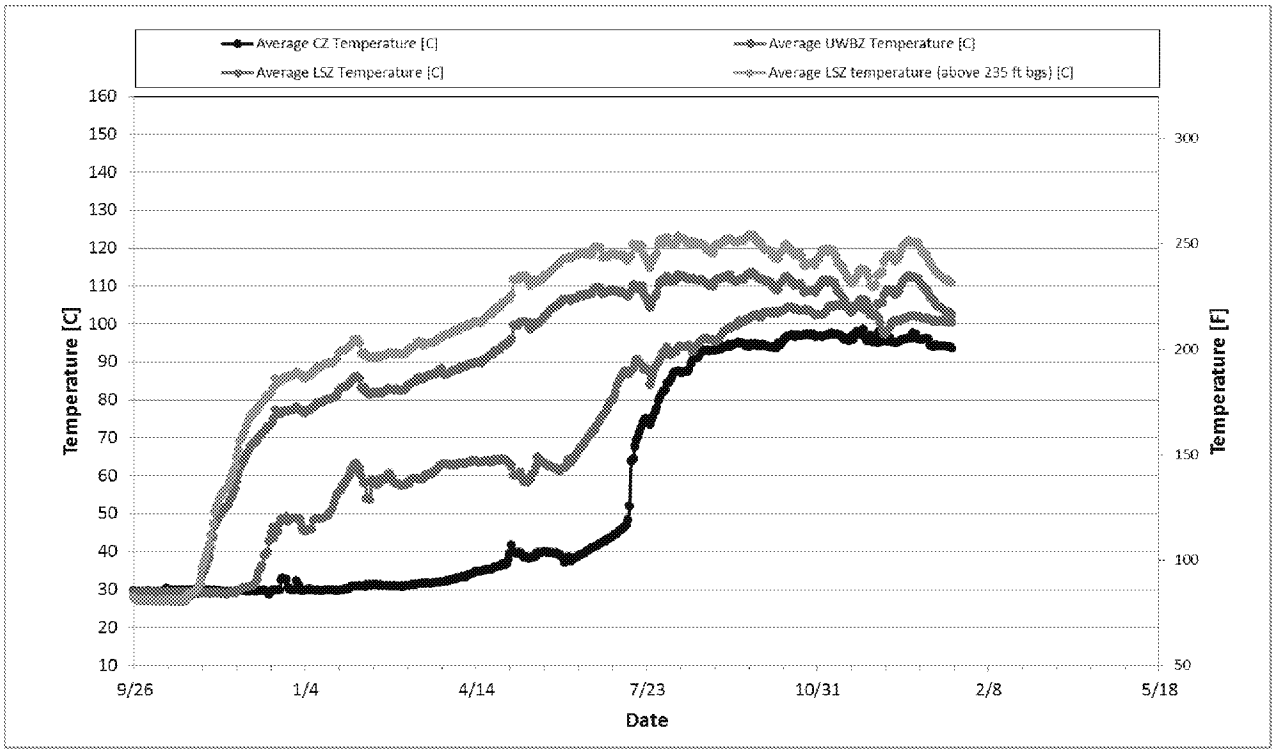
ST012 SEE to EBR Transition

Site ST012 SEE System
SEE to EBR Transition Criteria

- Criteria established to evaluate when the effectiveness of contaminant mass removal by SEE has diminished:
  - Primary SEE to EBR Transition Criteria
    - Achieve target subsurface temperatures
    - Diminishing mass removal rates
  - Secondary SEE to EBR Transition Criteria
    - Completion of Pressure Cycling: Repeat until no additional significant increases in effluent vapor concentrations observed when steam pressure is reduced
    - Benzene Concentrations: Target benzene concentration of 100 to 500 µg/L range within the TTZ (interior of the TTZ)
    - Steam Injection: Used as a guideline to measure progress vs. design
- Criteria are based on multiple lines of evidence. The criteria will be considered in total with the weight of evidence from these multiple lines being used for decisions. Individual compliance with each criteria is not absolute.

Subsurface Temperatures and Steam Breakthrough

Site ST012 SEE
Average Temperatures by Zone



- **Site-wide depressurization initiated on 28 December 2015**

CZ Target Treatment Temperature: ~100°C
UWBZ Target Treatment Temperature: ~114°C
LSZ Target Treatment Temperature: ~134°C

Site ST012 SEE TMP Maximum Depth-Averaged Temperature by Zone

Temperature Monitoring Point	Temperature Monitoring Point Maximum Depth-Averaged Temperature[1] (°C) During SEE Operations by Zone				
	CZ	UWBZ	LPZ	LSZ	LSZ (depths above 235 ft bgs)
TMP01	114.8	130.5	N/A	N/A	N/A
TMP03	N/A	N/A	137.5	114.2	120.7
TMP04	N/A	N/A	103.8	118.8	127.1
TMP05	110.3	N/A	N/A	N/A	N/A
TMP06	N/A	N/A	137.4	135.0	135.9
TMP07	N/A	N/A	134.6	137.2	140.2
TMP08	N/A	N/A	136.6	131.3	135.4
TMP09	N/A	N/A	132.5	134.1	139.3
TMP11	N/A	N/A	110.6	119.1	131.7
TMP12	75.7	90.3	121.8	121.4	131.3
TMP13	102.1	119.8	130.6	138.4	140.0
TMP14	N/A	N/A	133.6	124.3	136.3
TMP15	113.1	123.3	128.7	126.5	135.6
TMP16	N/A	N/A	126.7	120.5	131.0
TMP17	N/A	N/A	135.2	136.9	136.9
Maximum depth-averaged by zone[2]	**103.2**	**116.0**	**128.4**	**127.5**	**134.0**

If N/A, Temperature Monitoring Point has no sensors in that zone

[1] Temperature of the thermocouples across each depth zone are averaged for each TMP and each available time interval and then the maximum value of those averages throughout operations is listed in the table.

[2] Average of maximum depth-averages listed above for all TMPs in each zone.

- **Target treatment temperatures achieved in all zones (LSZ <235 ft bgs average is 134°C)**

CZ Target Treatment Temperature: ~100°C
UWBZ Target Treatment Temperature: ~114°C
LSZ Target Treatment Temperature: ~134°C

Site ST012 SEE
MPE Steam Breakthrough Achievement

Well	Well Location	Required to Reach Steam Temperature	Steam Breakthrough Achieved at MPE Temperature Calculated
CZ07	Perimeter	No	No
CZ08	Perimeter	No	No
CZ09	Perimeter	No	No
CZ10	Perimeter	No	Yes
CZ11	Interior	Yes	Yes
CZ12	Perimeter	No	Yes
CZ13	Perimeter	No	Yes
CZ14	Perimeter	No	Yes
CZ15	Interior	Yes	Yes
CZ16	Perimeter	No	Yes
CZ17	Perimeter	No	Yes
CZ18	Perimeter	No	No
CZ19	Perimeter	No	No
CZ20	Outside CZ	No	No

Well	Well Location	Required to Reach Steam Temperature	Steam Breakthrough Achieved at MPE Temperature Calculated
UWBZ01	Interior	Yes	Yes
UWBZ02	Interior	Yes	Yes
UWBZ04	Interior	Yes	Yes
UWBZ05	Interior	Yes	Yes
UWBZ06	Interior	Yes	Yes
UWBZ10	Perimeter	No	Yes
UWBZ17	Perimeter	No	Yes
UWBZ18	Interior	Yes	Yes
UWBZ19	Perimeter	No	Yes
UWBZ20	Dual Phase - Perimeter	No	No
UWBZ21	Outside UWBZ	No	No
UWBZ22	Perimeter	No	No
UWBZ23	Outside UWBZ	No	Yes
UWBZ24	Dual Phase - Perimeter	No	No
UWBZ26	Outside UWBZ	No	No
UWBZ27	Outside UWBZ	No	Yes

Well	Well Location	Required to Reach Steam Temperature	Steam Breakthrough Achieved at MPE Temperature Calculated
LSZ01	Interior	Yes	Yes
LSZ02	Interior	Yes	Yes
LZS04	Interior	Yes	Yes
LSZ05	Interior	Yes	Yes
LSZ06	Interior	Yes	Yes
LSZ08	Perimeter	No	Yes
LSZ11	Perimeter	No	Yes
LSZ12	Perimeter	No	No
LSZ13	Interior	Yes	Yes
LSZ14	Perimeter	No	No
LSZ15	Interior	Yes	Yes
LSZ16	Interior	Yes	Yes
LSZ17	Perimeter	No	Yes
LSZ28	Perimeter	No	Yes
LSZ29	Perimeter	No	No
LSZ30	Interior	Yes	Yes
LSZ31	Interior	Yes	Yes
LSZ32	Interior	Yes	Yes
LSZ33	Perimeter	No	Yes
LSZ34	Interior	Yes	Yes
LSZ35	Perimeter	No	Yes
LSZ36	Perimeter	No	Yes
LSZ37	Perimeter	No	Yes
LSZ38	Perimeter	No	Yes
LSZ39	Perimeter	No	No
LSZ40	Interior	Yes	Yes
LSZ42	Perimeter	No	Yes

- **Steam breakthrough has been achieved at all interior MPE wells**

Pressure Cycling and Mass Removal

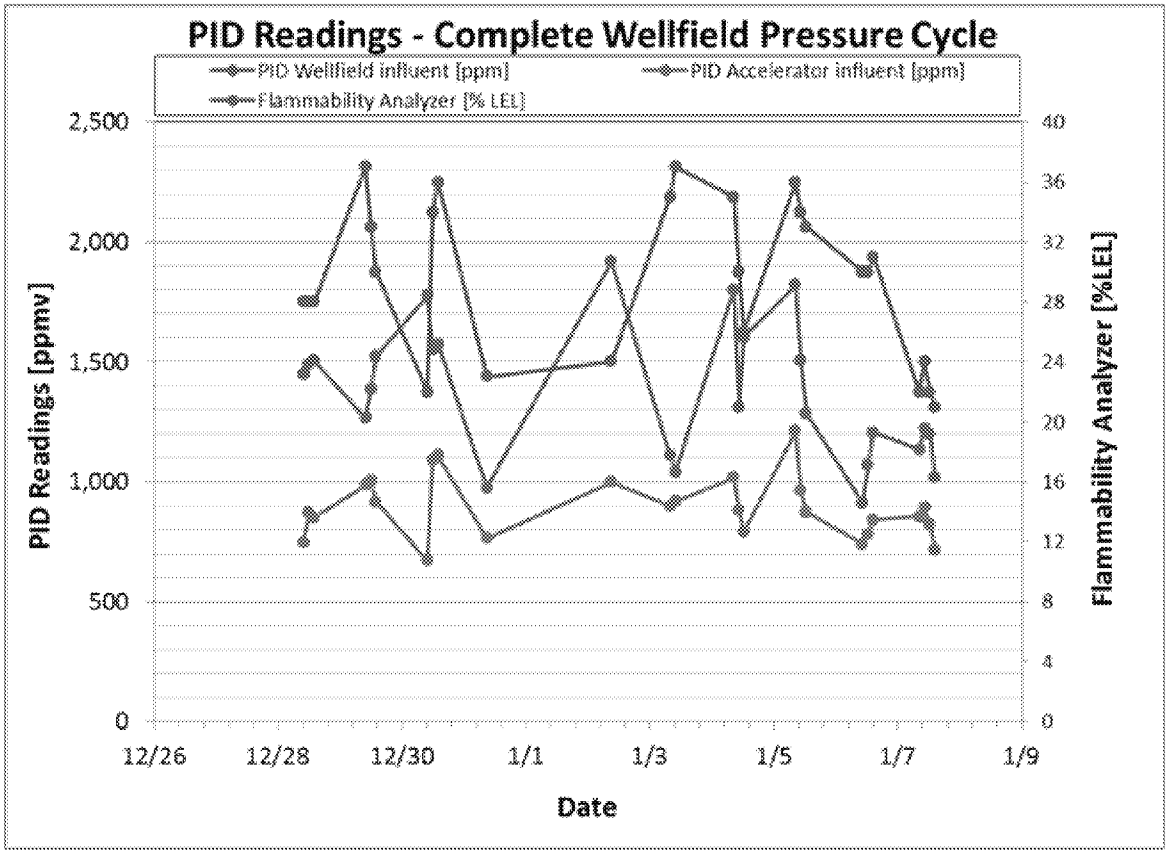
Pressure Cycling Status

- **Operational data reviewed to determine initiation of pressure cycling:**
  - **Multi-phase Extraction (MPE) Well Vapor Extraction Temperature**
  - **Temperature Monitoring Point Data**
  - **Calculated MPE Well Formation Temperature**
  - **Pressure cycling initiated to enhance benzene removal and to limit potential NAPL migration outside the TTZ**
  - **Pressure cycling status reviewed during the 27 May 2015 BCT call prior to initiation and again during the 24 June 2015 BCT call after it was initiated in the northern portion of the UWBZ**
  - **Pressure cycling status reviewed monthly on BCT calls**
  - **Pressure cycling currently synchronized in all zone – site-wide depressurization started 28 December 2015**
- **Pressure Cycling Status by Zone:**

	Pressurization or Depressurization Initiation Dates																				# Cycles Completed
CZ						6/30/15				9/17/15		10/7/15				11/11/15	11/20/15	11/25/15	12/3/15	12/28/15	3
UWBZ		12/4/14	6/8/15		6/22/15		7/24/15	8/12/15	8/26/15	9/17/15			10/14/15	10/30/15				11/25/15	12/3/15	12/28/15	5
LSZ	10/16/14			6/16/15			7/24/15	8/12/15	9/4/15		9/25/15	10/7/15				11/11/15	11/20/15	11/25/15	12/3/15	12/27/15	5

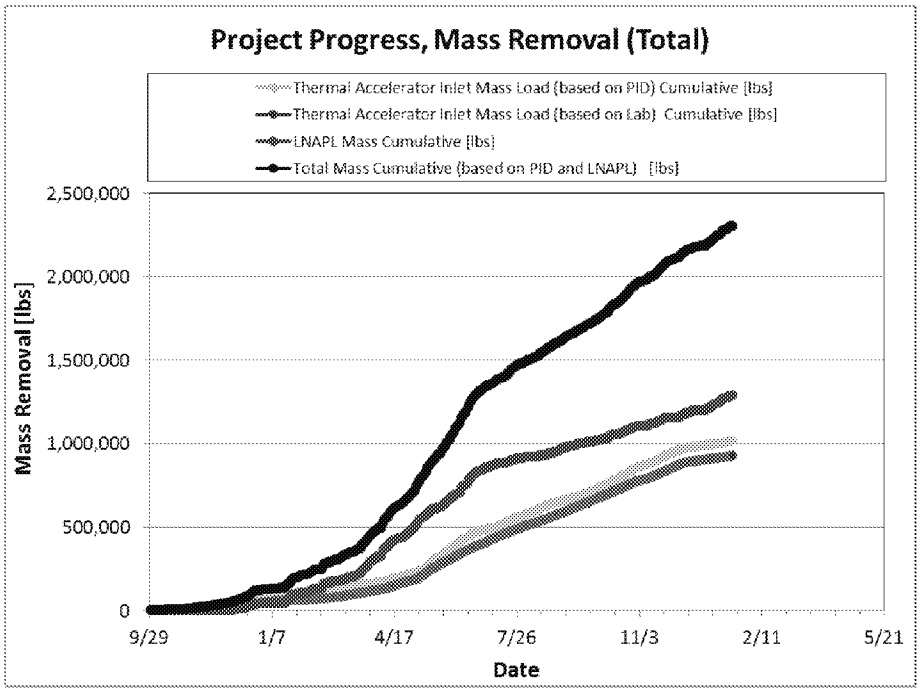
Pressurization
Depressurization

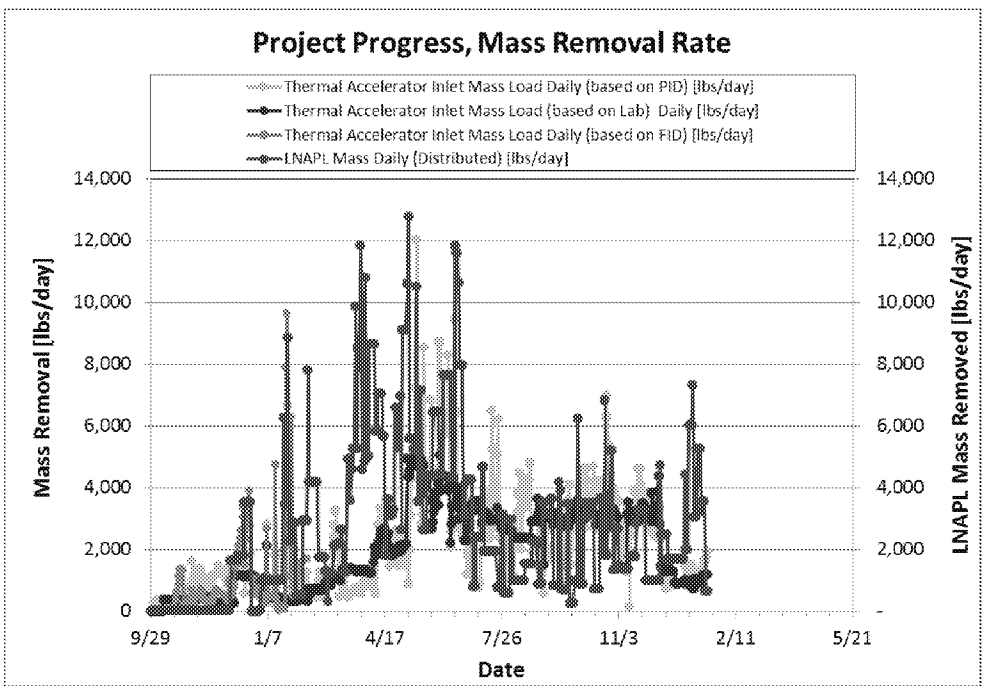
Site ST012 SEE System Pressure Cycling Vapor Screening



- PID frequency increased during initial phases of site-wide depressurization (~2-3 times per day)
- No obvious peak vapor concentrations detected – verified by simultaneously collected %LEL measurements

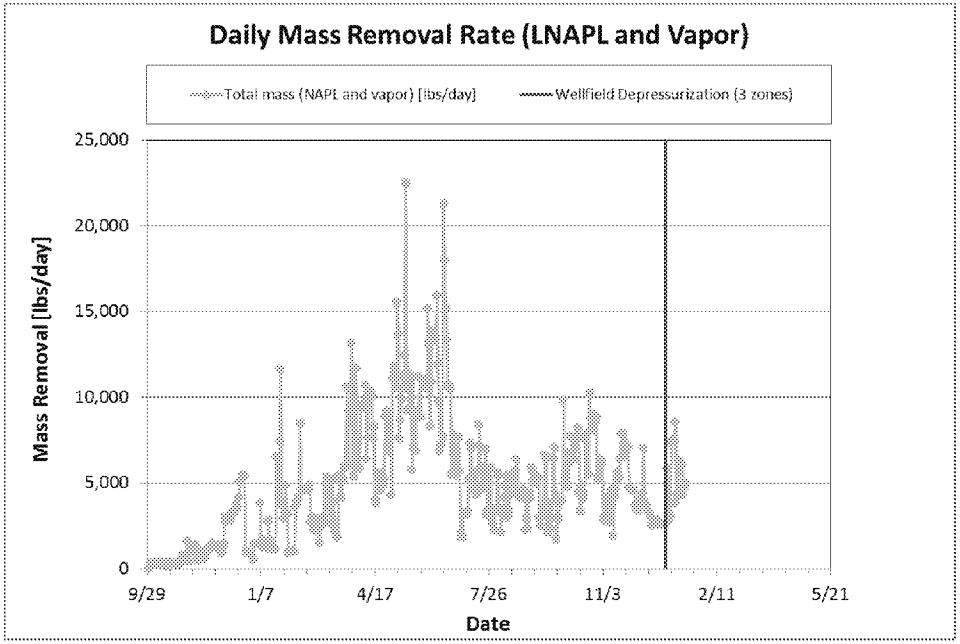
Site ST012 SEE System Mass Removal

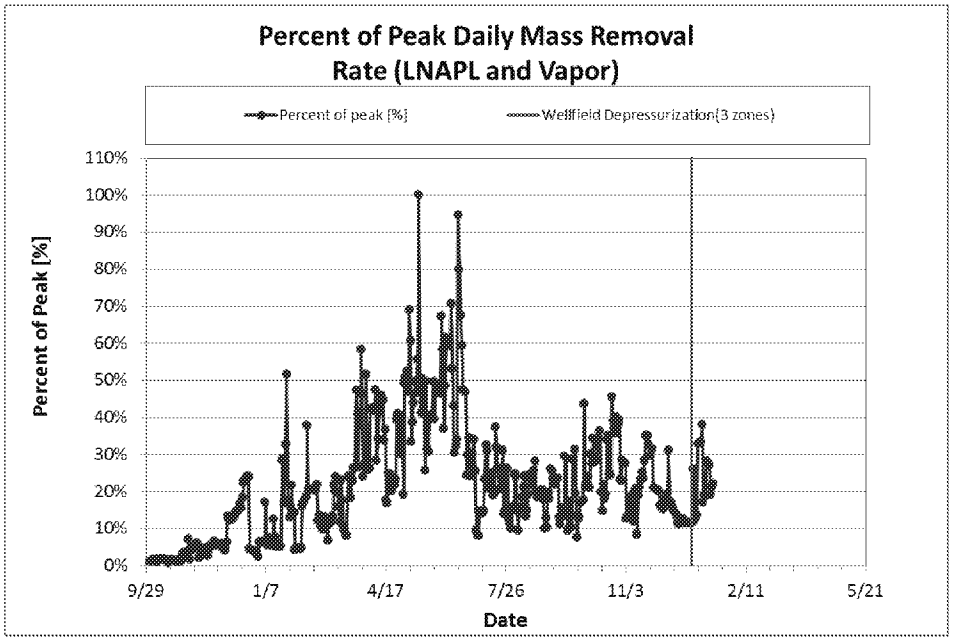




- **Total Contaminant Mass Removal: 2,302,951 lbs recovered**
- **An estimated 1,286,793 lbs (195,859 gallons) as non-aqueous phase liquid (NAPL)**
- **An estimated 1,016,158 lbs of mass (PID) removed in the vapor phase**

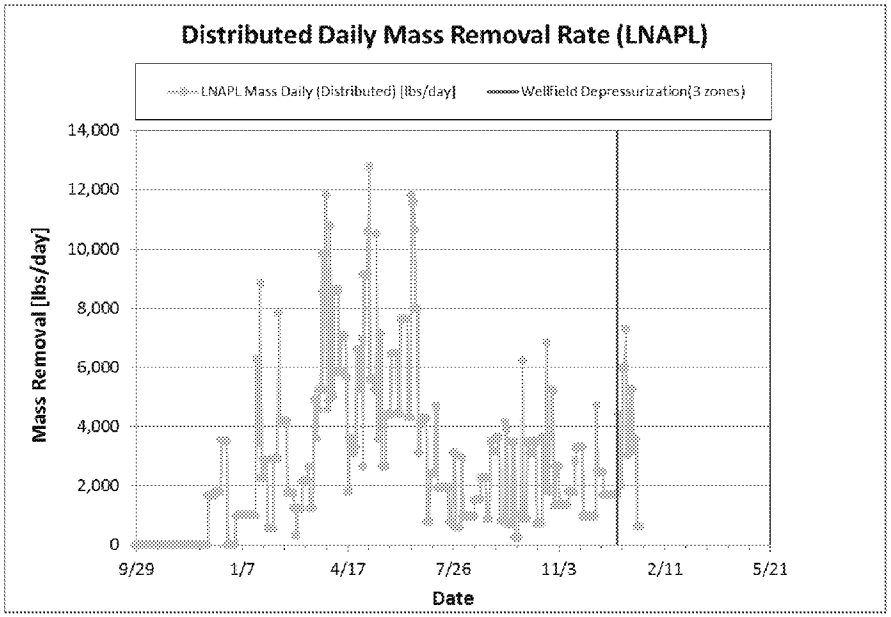
Site ST012 SEE System Daily Mass Removal

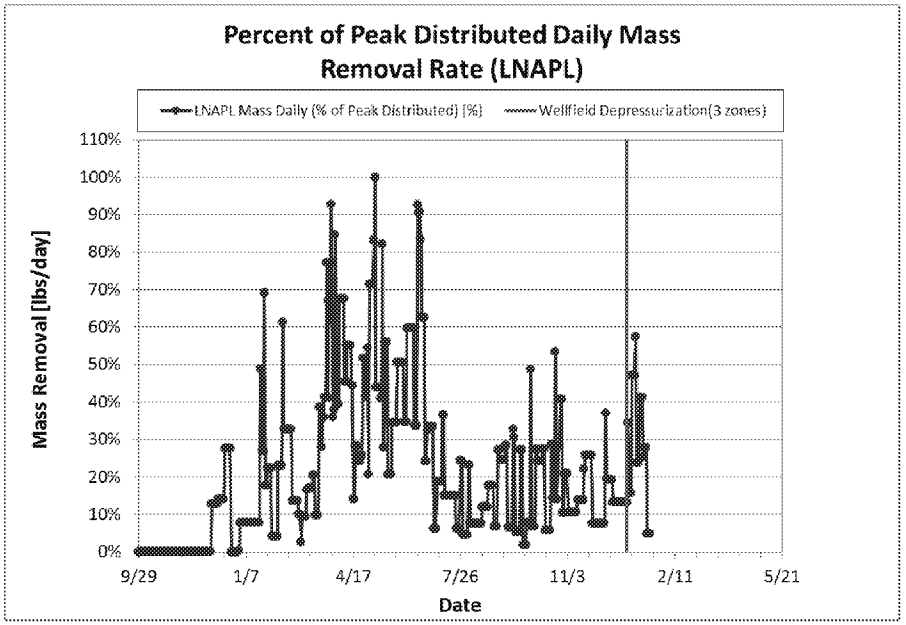




- **Mass removal target of ~10% of peak is appropriate for ST012 because of the follow-on EBR and natural attenuation planned**
- **Mass removal peaked on 14 May 2015 at 22,506 lbs/day**
- **Mass recovery is 20-40% of the peak during the site-wide depressurization.**

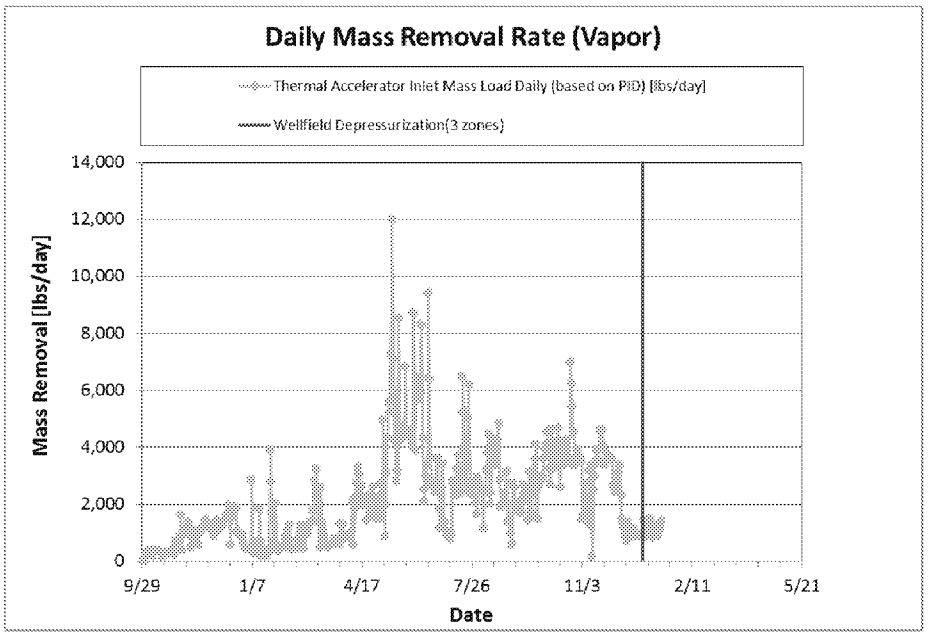
Site ST012 SEE System
Daily Mass Removal

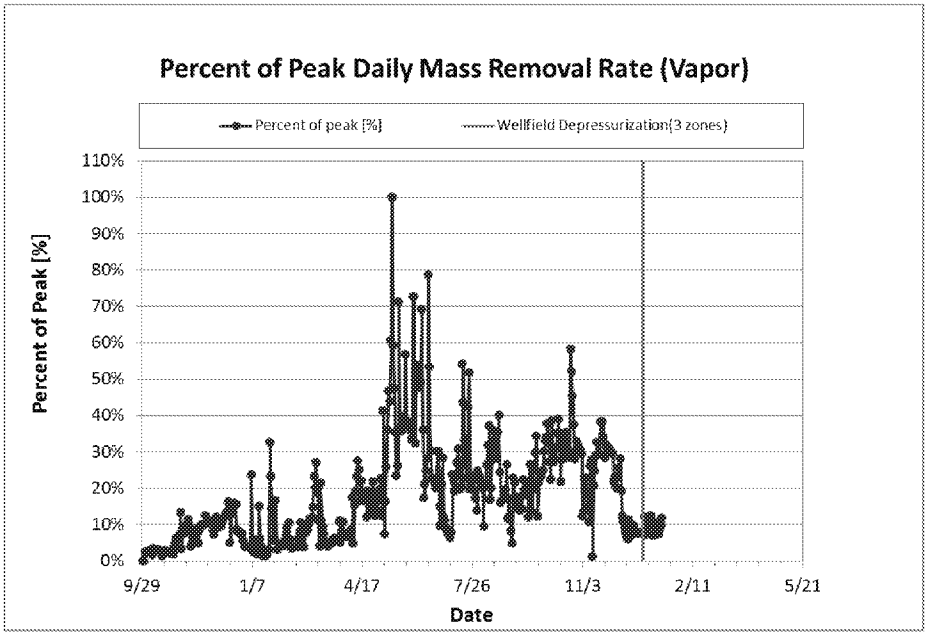




- Daily LNAPL mass removal peaked on 5 May 2015 at 12,760 lbs/day
- Increase in overall mass removal during the site-wide depressurization predominately due to increase in LNAPL recovery.
- LNAPL recovery during the site-wide depressurization is 20-60% of the peak

Site ST012 SEE System
Daily Mass Removal

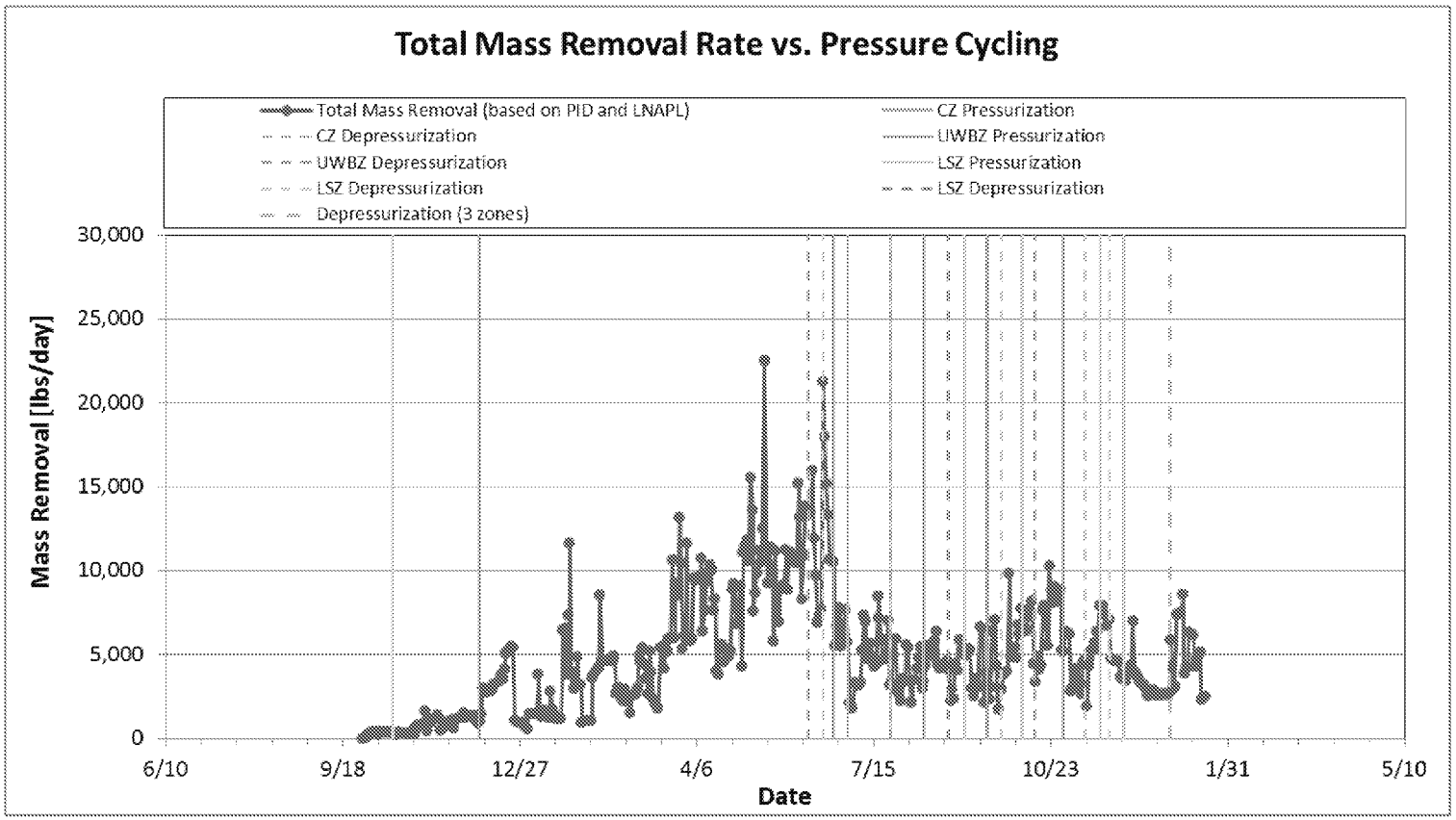




- **Daily vapor mass removal peaked on 14 May 2015 at 12,009 lbs/day**
- **Vapor mass removal rates are 10-15% of the peak during the site-wide depressurization**

Pressure Cycling and Mass Removal

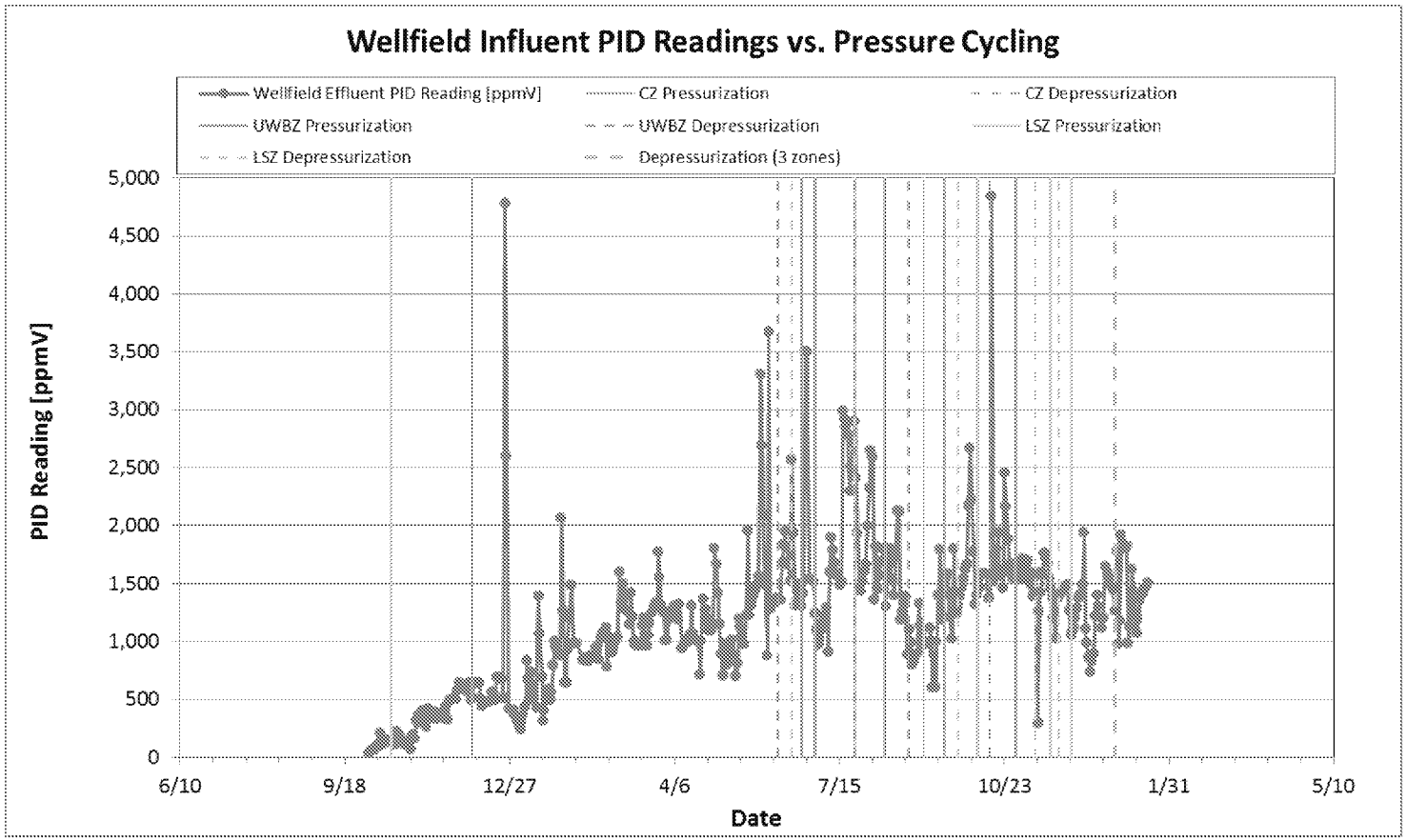
Mass Removal over Time



- **Peak mass removal occurred April – June 2015 (vapor and NAPL phases)**

Pressure Cycling and Vapor Concentrations Over Time

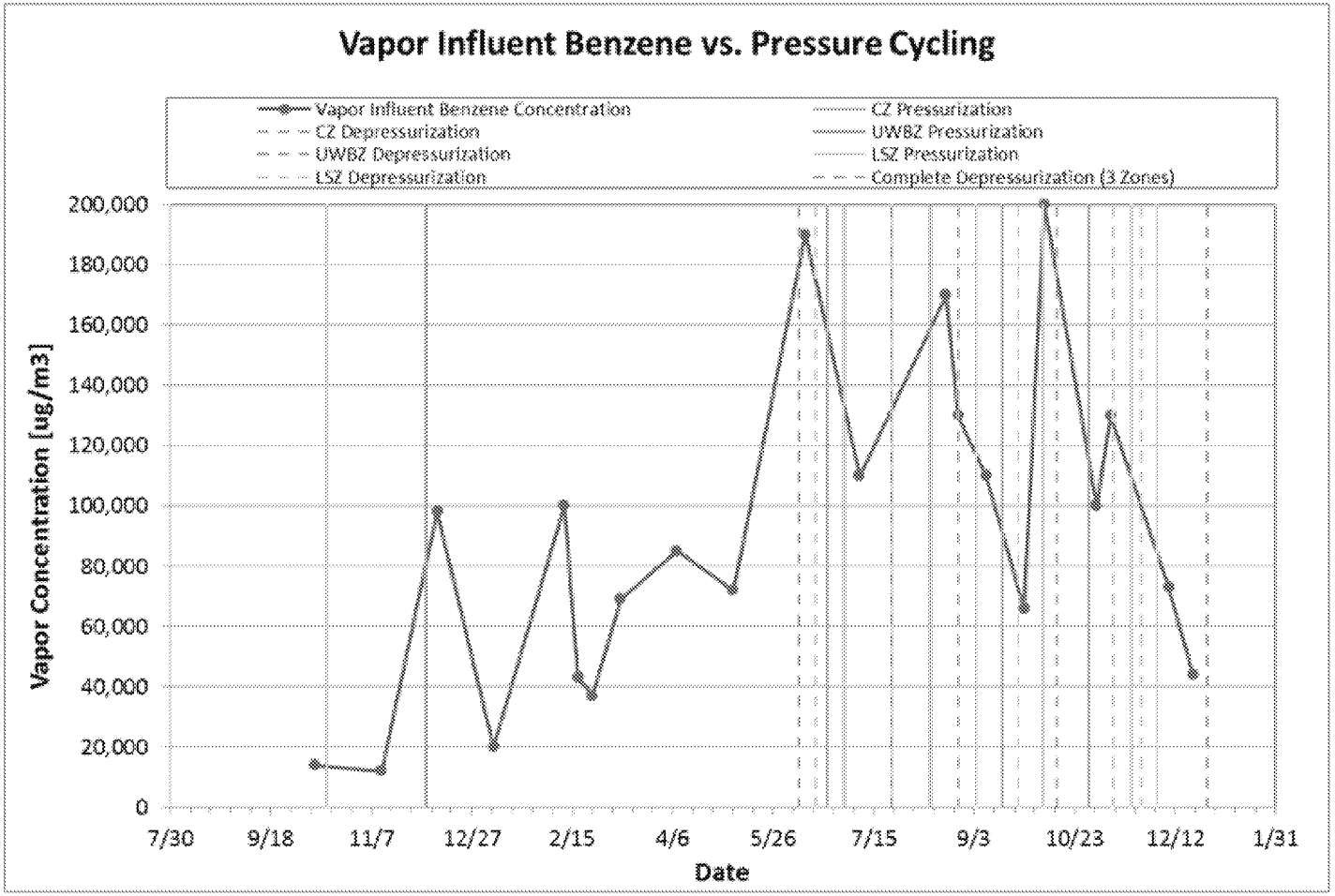
Wellfield Vapor Influent PID Concentrations over Time



- **Vapor phase removal fluctuated during the site-wide depressurization**

Pressure Cycling and Benzene Vapor Concentrations Over Time

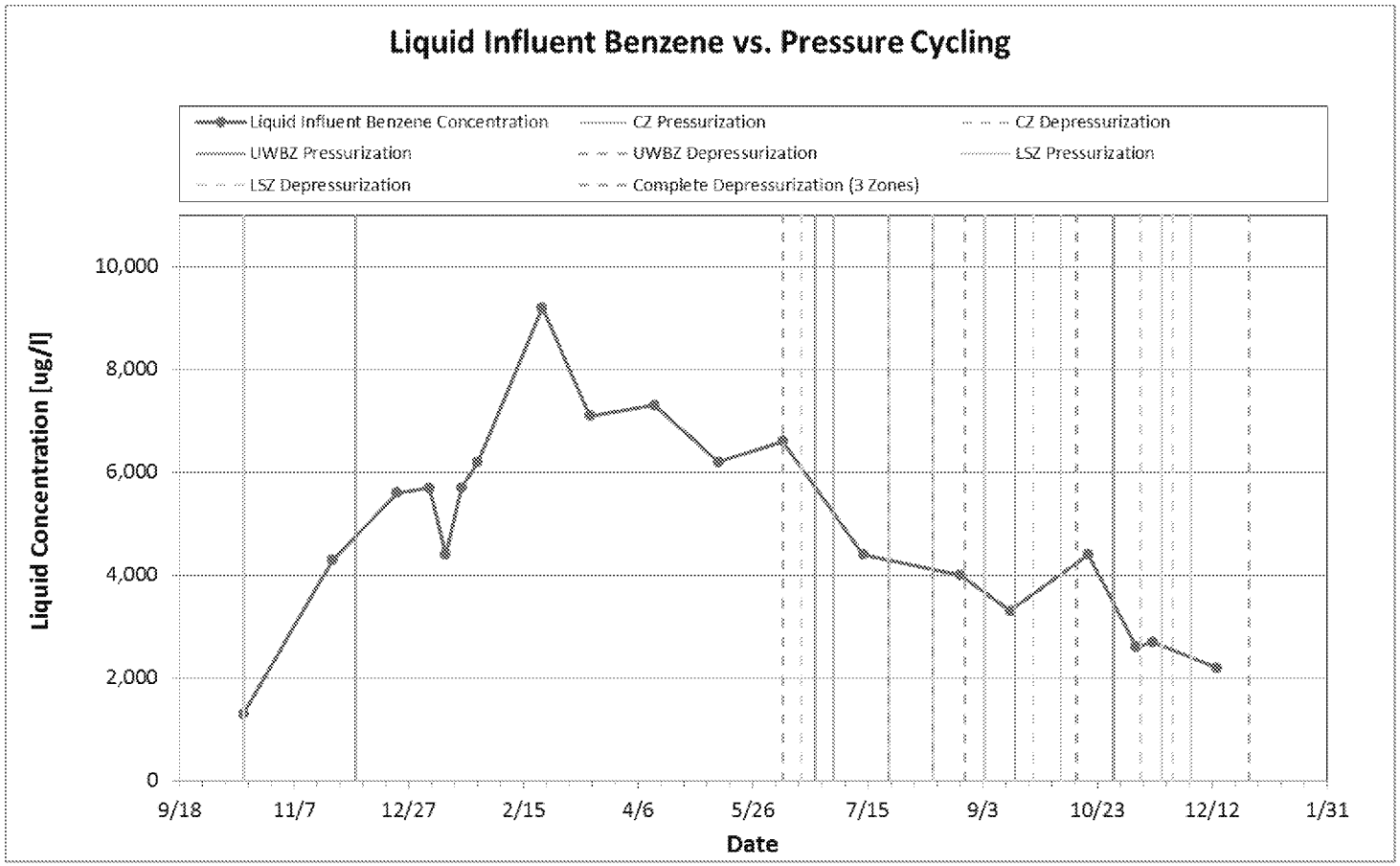
Extracted Vapor Benzene Concentrations over Time
(measured at thermal accelerator influent [includes air stripper effluent] by EPA Method TO-15)



- **Benzene concentrations have fluctuated during pressure cycling**

Pressure Cycling and Benzene Liquid Concentration Over Time

Extracted Liquid Benzene Concentrations over Time (measured at air stripper influent by EPA Method 8260B)



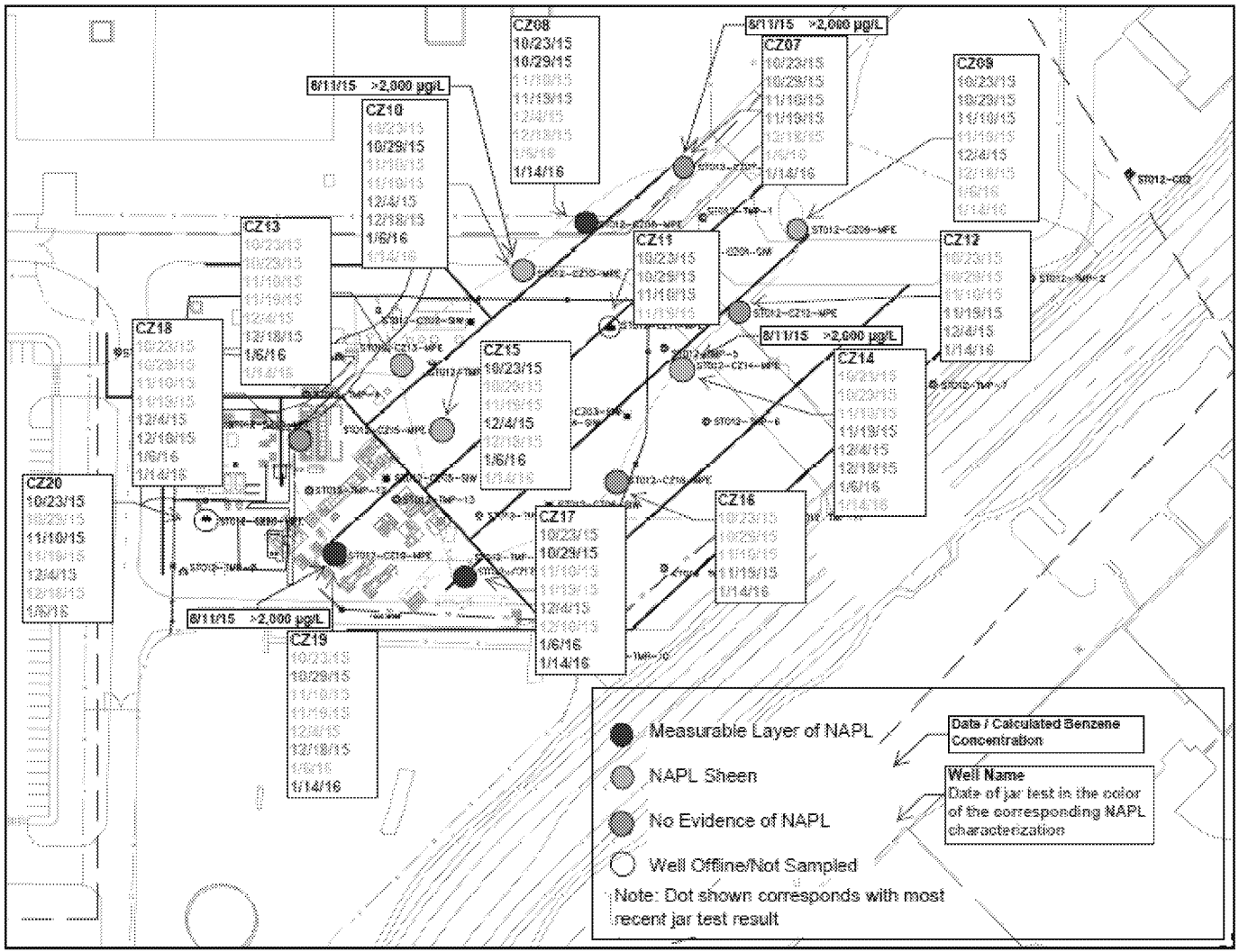
- **Benzene concentrations have declined**

Benzene Concentrations in Groundwater and NAPL Delineation

Site ST012 SEE System Benzene Concentrations

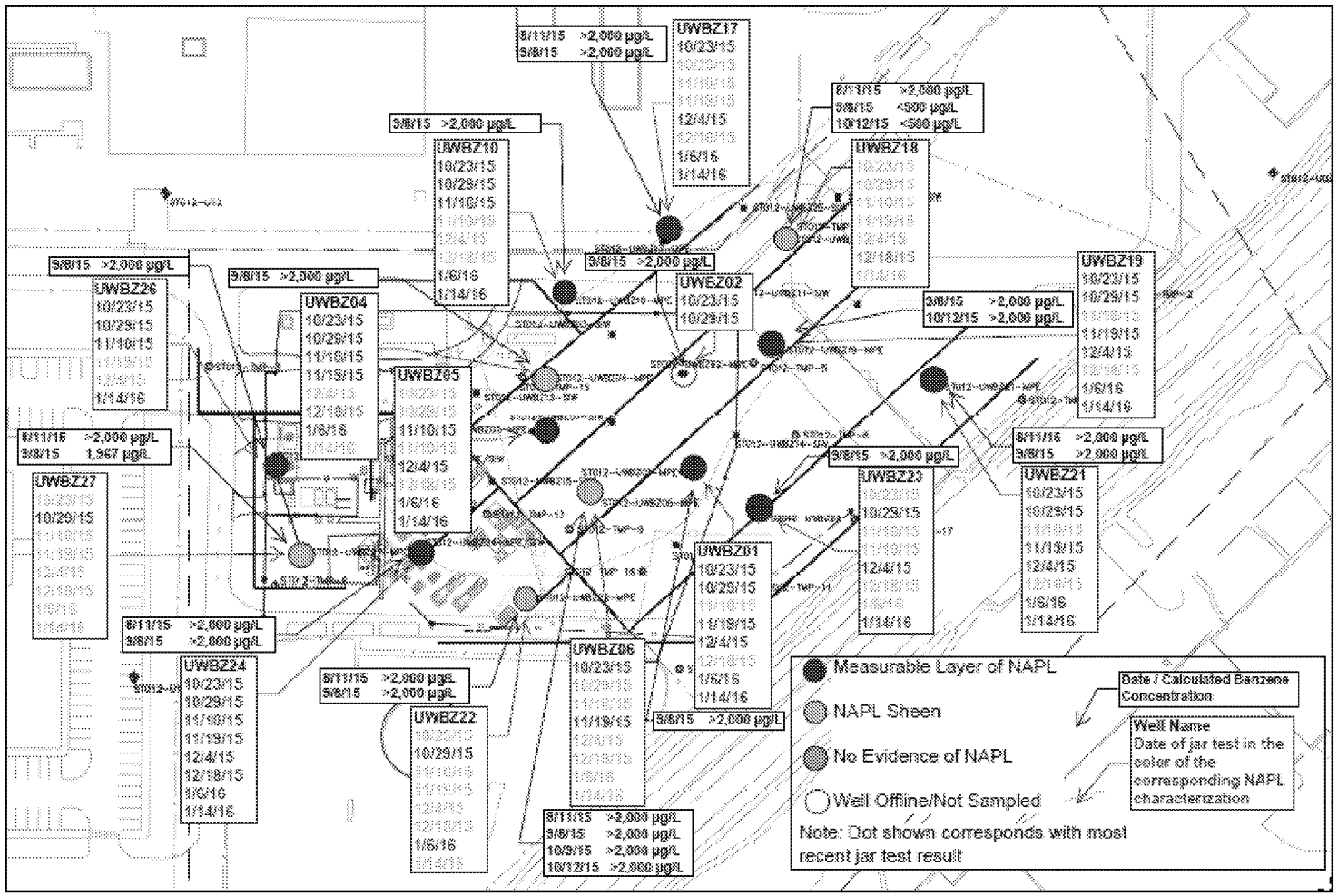
- 100 to 500 µg/L was set as the goal for SEE in the TTZ interior as the concentration range where natural attenuation can complete complete degradation within the remedy timeframe (20 years post ROD)
- Groundwater concentrations above 500 µg/L expected to remain at TTZ perimeter because of known contamination outside of TTZ.
- Contribution from perimeter likely enhanced by elevated temperatures (increased dissolution and solubility)
- Groundwater concentrations may also be above 500 µg/L in some areas of TTZ interior because of contribution from perimeter groundwater (i.e., extracted groundwater at interior MPE wells originates as a combination of condensed steam and perimeter groundwater that has been pulled to the interior)
- Concentrations above 500 µg/L (as high as 5,500 µg/L in RD/RAWP model) in the TTZ can be addressed through EBR
  - Depletion of LNAPL in TTZ interior leaves mainly dissolved phase BETX
  - Sulfate injected at perimeter will migrate and contribute to reductions in TTZ interior
  - EBR treatment of perimeter will reduce further perimeter contributions to TTZ interior
  - Additional sulfate can be injected in TTZ if necessary

NAPL Screening Results and Calculated Benzene Concentrations – Cobble Zone August 2015 – January 2016



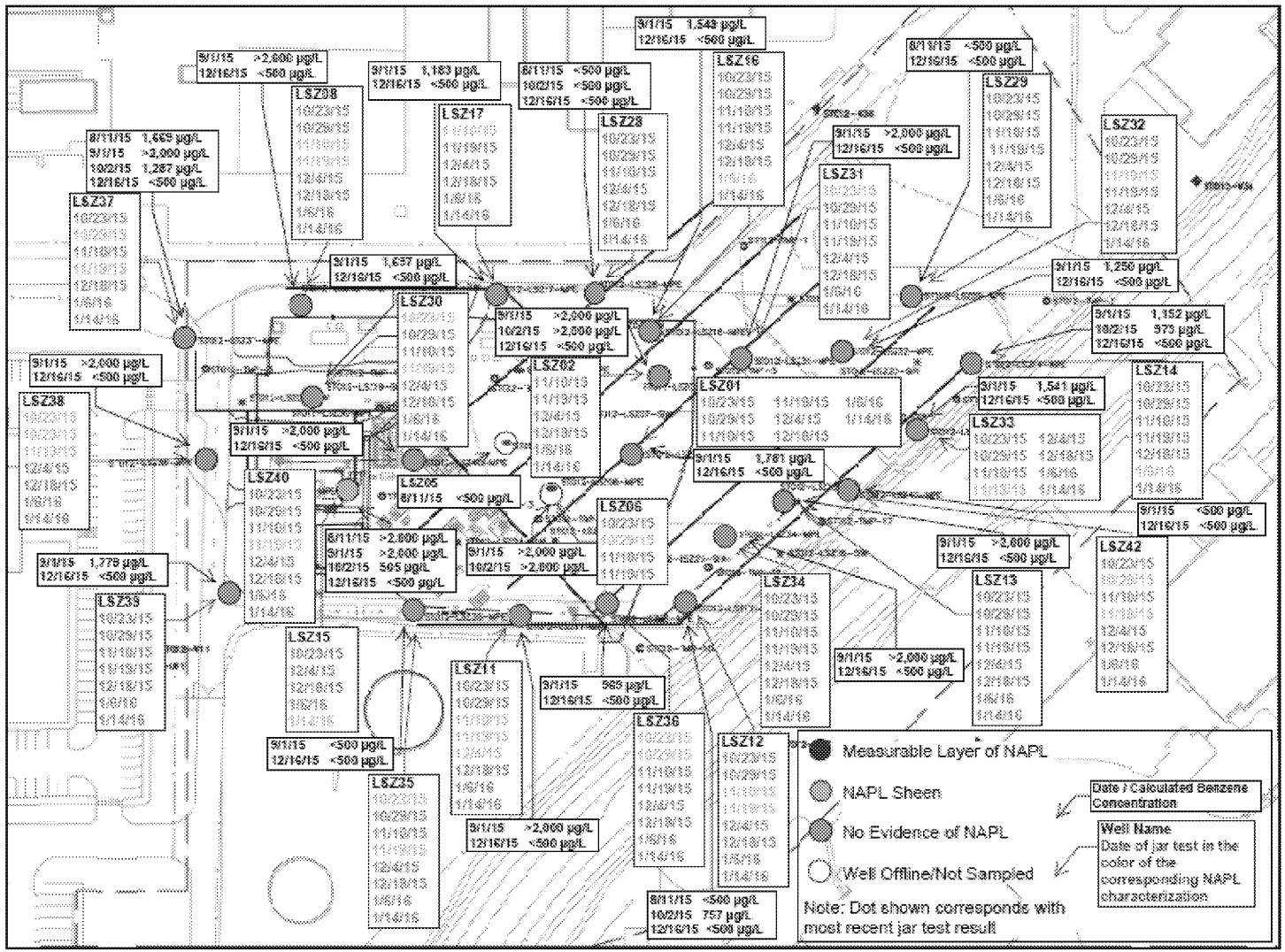
- Site wide depressurization initiated 28 December 2015
- NAPL screening results showed increase in measurable layers of NAPL and NAPL sheens post-depressurization

NAPL Screening Results and Calculated Benzene Concentrations – Upper Water Bearing Zone August 2015 – January 2016



- Site wide depressurization initiated 28 December 2015
- NAPL screening results showed increase in measurable layers of NAPL and NAPL sheens post-depressurization

NAPL Screening Results and Calculated Benzene Concentrations – Lower Saturated Zone August 2015 – January 2016



- Calculated benzene concentrations <500 µg/L at all locations for 16 Dec 2015 event
- Site wide depressurization initiated 28 December 2015
- NAPL screening results showed no increase in measurable layers of NAPL and slight increase in NAPL sheens at one or two locations post-depressurization

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SEE to EBR Transition Criteria

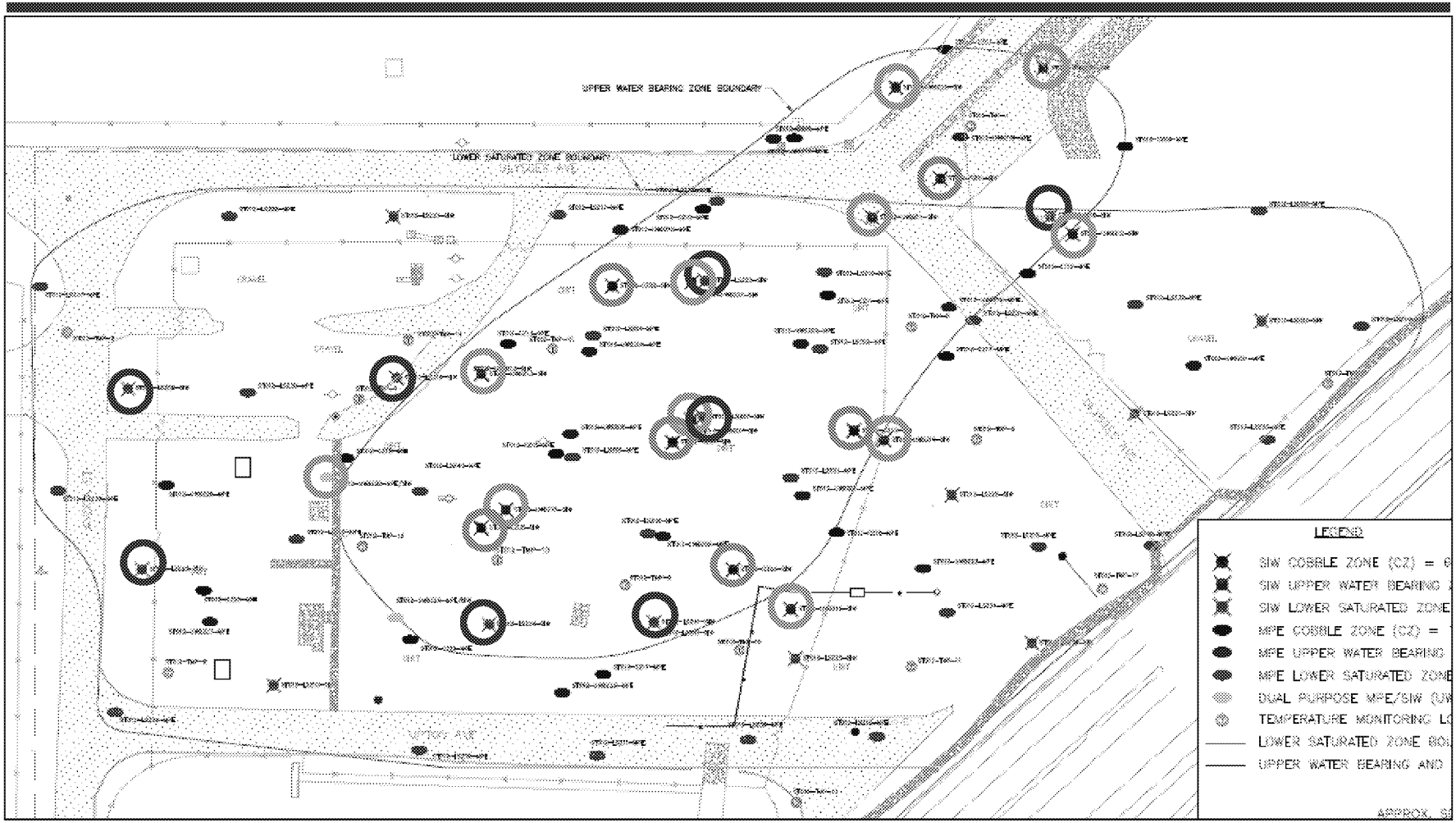
SEE to EBR Transition Criteria Progress

Transition Criteria	Progress
Target Temperature Achievement	• CZ: Average target temperature achieved • UWBZ: Average target temperature achieved • LSZ: Average temperature achieved (depths above 235 ft bgs) • Steam breakthrough observed at all interior MPE wells
Pressure Cycling Status	• CZ: Currently in the fourth pressurization/depressurization cycle • UWBZ: Currently in the sixth pressurization/depressurization cycle • LSZ: Currently in the sixth pressurization/depressurization cycle
Mass Removal Status	• Peak mass removal occurred April – June 2015 (vapor and NAPL phases) • Significant increase in NAPL production during site-wide depressurization
Benzene Concentrations	• Benzene concentration target achieved in the LSZ • NAPL production still evident in CZ and UWBZ so benzene target not likely reached. Perimeter NAPL contribution may be limiting progress.
Steam Injection Status (guideline)	• 285 MM lbs injected versus 320 MM operations guide – lower permeability zones accepting less steam than modeled. • Achieved flushing of 1.7 pore volume (1.5 pore volume design) – not a NAPL depletion design but a benzene reduction design, thus less than 2 pore volumes seen at other sites • Steam quantity or pore volume flush not a major metric – benzene content in TTZ is (driving polishing phase)

Site ST012 SEE System Path Forward

- Primary transition criteria met for LSZ (temperatures and mass removal). Pressure cycling currently ongoing in all three zones.
- Discontinue steam injection in the perimeter LSZ wells – maintain interior LSZ steam injection to facilitate heating in the UWBZ
- Coordinated pressure cycle ongoing (all zones simultaneously) – no significant increases in vapor concentrations have been observed, significant increase in NAPL recovery observed
- Sampling/cycling frequency:
  - Continue ~weekly jar test results
  - Collect groundwater samples in the UWBZ and CZ late January
  - Another site-wide depressurization in early February
  - Another re-pressurization in mid February
  - Shutdown of steam – end of February
  - Post steam extraction to begin in Mar 2016
- Sample frequency is dynamic in response to results received at each round.

Site ST012 Steam Injection Strategy Path Forward



LSZ wells online (8)

UWBZ wells online (11)

CZ wells online (6)